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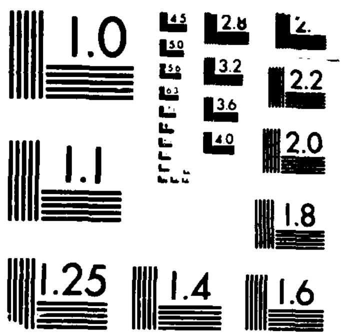

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Substantial contributions have been made to the understanding of fundamental processes in two-dimensional inviscid and nearly dissipationless vortex dynamics through an approach we call complementary modeling. We have identified and studied physical-space procesees like merger, binding, axisymmetrization-and-gradient-intensification of near-isolated regions of vorticity. We have employed a variety of algorithms and codes including pseudo-spectral, contour dynamical, and our recently introduced moment model. Through the last application, we have solved analytically an asymptotical representation of the symmetric merger problem and provided causes and conditions for merger that agree with pseudospectral and contour dynamical simulations. We have also delineated the essential parameters which control the final state of two nonidentical nearby vortices (asymmetric merger).

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VORTEX DYNAMICS OF COHERENT AND CHAOTIC STRUCTURES

(Including Algorithms for Computer Simulations

and Diagnosis)

FINAL REPORT

(1 September 1984 - 31 August 1987)

N. J. ZABUSKY

December 20, 1987

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VORTEX DYNAMICS OF COHERENT AND CHAOTIC STRUCTURES

(Including Algorithms for Computer Simulations

and Diagnosis)

Proposal No. 21371-MA

During this three year period we made substantial contributions to the understanding of fundamental processes in two-dimensional inviscid and nearly dissipationless vortex dynamics through an approach we call complementary modeling. We have identified and studied physical-space processes like merger, binding, axisymmetrization-and-gradient-intensification of near-isolated regions of vorticity. We have employed a variety of algorithms and codes including pseudo-spectral, contour dynamical, and *our* recently introduced moment model. Through the last application, we have solved analytically an asymptotical representation of the symmetric merger problem and provided causes and conditions for merger that agree with pseudospectral and contour dynamical simulations. We have also delineated the essential parameters which control the final state of two nonidentical nearby vortices (asymmetric merger)

We have established an Interactive Graphics and Numerical Diagnostics Laboratory to examine data from large-scale computer simulations. This uses SUN Microsystems and Hitachi hardware (SUN models 2/120). This allows us to diagnose or "project" large quantities of field data like vorticity or velocity, into lower dimensional forms. The system will accelerate the creative process and will enhance the productivity of scientists and engineers in computational science.

As a result of interactions with government laboratory personnel at the ARO sponsored Blade-Vortex interaction workshop at NASA Ames, we began a consideration of compressible and 3D vortex dynamics. Work with F. Lund presented a new formalism to treat perturbation terms normally omitted from "aeroacoustic" theory which give the effect of sound on vortex motions. This was made explicit in *3D* for the local induction approximation. M. V. Melander took the lead in examining the 3D incompressible evolution of two offset-orthogonal

Gaussian vortex distributions, namely, the "reconnection" problem, a quintessential process in 3D turbulence and one which is probably the chief cause of intermittency. His low dissipation 64^3, 96^3, and 128^3 dealiased spectral simulations iof the Navier-Stokes equations show an inviscid *entanglement* on a convective time scale which yields an *apparent* visual reconnection when the vorticity distributions are "coarse grained." The essential interactions of "hairpin"-like structures pulled orthogonally from the original cores and "spikes" ejected from the close binding of oppositely directed vortex tubes are features that dominate the inviscid entanglement process..

Toward the end we initiated a collaboration with K.-H. Winkler of Los Alamos and P. L. Woodward of the University of Minnesota. We have done simulations at Los Alamos and used their ultra-speed graphics facility. Using Woodward's PPM code, we have simulated the interaction of an $M = 1.25$, 2.5 and 3.0 shock with heavy and light bubbles, in 2D axisymmetry (z,r), and overlapped the parameter region of the Haas-Sturtevant (Caltech) experiments. The break-up of bubbles, primarily by vortex deposition at the interface is under investigation. A paper on the subject was submitted to the Tokyo meeting on Fundamentals of Vortex Motion and a prelimnary account was published in "A Numerical Laboratory," *Phys. Today*, October 1987. This work has potential relevance for the *multiple* nuclear burst in a dust (inhomogeneity) filled environment.

We believe the last three areas represent virgin territory in computational and mathematical fluid dynamics and are relevant to many DOD applications. We hope that funds will be available to us soon to pursue these areas.

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